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Applying electrical resistivity tomography and biological methods to assess the surface-groundwater interaction in two Mediterranean rivers (central Spain)

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Delineation of the extent of hyporheic zone (HZ) in river ecosystems is problematic due to the scarcity of spatial information about the structure of riverbed sediments and the magnitude and extent of stream interactions with the parafluvial and riparian zones. The several existing methods vary in both quality and quantity of information and imply the use of hydrogeological and biological methods. In the last decades, various non-invasive geophysical techniques were developed to characterise the streambed architecture and also to provide detailed spatial information on its vertical and horizontal continuity. All classes of techniques have their strengths and limitations; therefore, in order to assess their potential in delineating the lateral and vertical spatial extents of alluvial sediments, we have combined the near-surface images obtained by electrical resistivity tomography (ERT) with biological assessment of invertebrates in two Mediterranean lowland rivers from central Spain.

We performed in situ imaging of the thickness and continuity of alluvial sediments under the riverbed and parafluvial zone during base-flow conditions (summer 2013 and winter 2014) at two different sites with distinct lithology along the Tajuña and Henares Rivers. ERT was performed by installing the electrodes (1 m spacing) on a 47 m long transect normal to the river channel using a Wener-Schlumberger array, across both the riparian zones and the river bed. Invertebrates were collected in the streambed from a depth of 20-40 cm, using the Bou-Rouch method, and from boreholes drilled to a depth of 1.5 m in the riparian zone.

The ERT images obtained at site 1 (medium and coarse sand dominated lithology) shows resistivity values ranging from $\sim$20 to 80 ohm•m for the in-stream sediments, indicating a permeable zone up to $\sim$ 0.5 m thick and extending laterally for ca. 5 m from the channel. These sediments contribute to active surface/hyporheic water exchanges and to low water retention in stream sediments, as also indicated by the similar physico-chemical parameters in thw two zones, and the composition of hyporheic biota, dominated exclusively by surface-dwellers (e.g. Cladocera, Chironomidae, Cyclopoida (Microcyclops rubellus), Ostracoda (Pryonocypris zenkeri). A low resistivity (< 70 ohm•m) permeable zone located at 2.3 m depth bellow the streambed and unconnected with the river channel was also detected and associated with a shallow floodplain aquifer. In contrast, the resistivity image at site 2 (fine and very fine sand dominated lithology) shows a low permeability zone in the upper $\sim$ 0.5 m of the profile, with resistivity values ranging from $\sim$45 to 80 ohm•m, indicating a reduced HZ extension in both vertical and lateral dimensions. Here, both water retention and interaction between water and sediments are higher than at site 1 and consequently the water chemistry is distinct from that of the river channel (lower conductivity, temperature and dissolved oxygen in hyporheic waters). These features of the sedimentary layers create suitable habitats conditions in HZ for the development of a mixture of both epigean (e.g., Ostracoda (Darwinula stevensoni)) and hypogean stygobites dwellers (e.g., Cyclopoida (Acanthocyclops n. sp)). Furthermore, a low resistivity (< 30 ohm•m) high permeability zone was detected 2 m from the riverbed, at a depth of ca. 3 meters, being associated either to a suspended aquifer supplied with water from the terraces, or to water accumulation within tree roots, that might be temporary connected with the stream-hyporheic system.

The two examples show that non-invasive ERT images and biological assessment provides complementary and valuable information about the characterisation of the sub-channel architecture and its potential connection with the parafluvial and riparian zones. Our results provide initial templates for high-resolution in situ studies with broad and integrated methods to identify the boundaries between hyporheic and parafluvial zones and the time-scale fluctuations in response to water exchanges with the surface stream.